

THAT WHICH IS CLAIMED IS:

1. An apparatus for making bellows from bellows components, the apparatus comprising:

5 a fixture for supporting a plurality of bellows components in side-by-side relation to define a plurality of pairs of adjacent outer edges to be welded together;

10 a reference point determining device for determining at least one reference point relating to locations of the pairs of adjacent outer edges of bellows components supported on said fixture;

a laser for generating a laser beam;

a positioner for relatively positioning the laser beam and said fixture; and

15 a controller for controlling said laser and said positioner so that the laser beam welds together the pairs of adjacent outer edges based upon the at least one reference point.

2. An apparatus according to Claim 1 wherein the at least one reference point comprises a reference point on at least one of said pairs of adjacent outer edges.

3. An apparatus according to Claim 1 wherein the at least one reference point comprises a respective reference point on each of said pairs of adjacent outer edges.

4. An apparatus according to Claim 1 wherein the at least one reference point comprises a plurality of spaced apart reference points for at least one of

said pairs of adjacent outer edges.

5. An apparatus according to Claim 4 wherein said controller causes the laser beam to follow a predetermined function between successive points.

6. An apparatus according to Claim 5 wherein the predetermined function comprises at least one of a linear function, a logarithmic function, a polynomial function, a power function, an exponential function, and a function based on a moving average.

7. An apparatus according to Claim 4 wherein said controller determines an average reference point based upon the plurality of reference points.

8. An apparatus according to Claim 1 wherein the at least one reference point comprises a reference point on said fixture.

9. An apparatus according to Claim 1 wherein said controller controls said laser and said positioner to cause the laser beam generated by said laser to impinge on at least one welding point relating to locations of the pairs of adjacent outer edges of bellows components positioned on said fixture, and wherein the at least one welding point is within a predetermined distance of the at least one reference point.

10. An apparatus according to Claim 1 wherein said laser provides an enlarged beam coverage area to weld each pair of adjacent outer edges despite

slight errors in relative positioning of the laser beam
5 and pair of adjacent outer edges.

11. An apparatus according to Claim 1
wherein said laser provides a plurality of laser beams
to simultaneously weld multiple pairs of adjacent outer
edges.

12. An apparatus according to Claim 1
wherein said reference point determining device
comprises:

a optical system for presenting to an
5 operator an image of at least one pair of adjacent
edges; and

an input device for accepting from an
operator an input to set the at least one reference
point for use by said controller.

13. An apparatus according to Claim 12
wherein said optical system presents a magnified image
of the at least one pair of adjacent edges.

14. An apparatus according to Claim 12
wherein said optical system comprises a camera and a
display connected thereto.

15. An apparatus according to Claim 12
wherein said camera comprises an infrared camera.

16. An apparatus according to Claim 1
wherein said reference point determining device

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comprises a sensor connected to said controller.

17. An apparatus according to Claim 1 wherein the bellows components comprise at least one end plate.

18. An apparatus according to Claim 1 wherein the bellows components comprise a plurality of bellows diaphragms.

19. An apparatus according to Claim 1 wherein said fixture comprises a rotatable arbor and a drive motor connected thereto.

20. An apparatus for making bellows from bellows components, the apparatus comprising:

a fixture for supporting a plurality of bellows components in side-by-side relation to define a plurality of pairs of adjacent outer edges to be welded together;

a laser for generating a laser beam;

a positioner for relatively positioning the laser beam and said fixture;

an optical system for presenting to an operator an image of at least one pair of adjacent edges;

an input device for accepting from the operator an input to set at least one reference point relating to locations of pairs of adjacent outer edges of bellows components supported on said fixture; and

a controller for controlling said laser and said positioner so that the laser beam welds together the pairs of adjacent outer edges based upon the at

20 least one reference point.

21. An apparatus according to Claim 20 wherein said optical system presents a magnified image of the at least one pair of adjacent edges.

22. An apparatus according to Claim 20 wherein said optical system comprises a camera and a display connected thereto.

23. An apparatus according to Claim 22 wherein said camera comprises an infrared camera.

24. An apparatus according to Claim 20 wherein the at least one reference point comprises a reference point on at least one of said pairs of adjacent outer edges.

25. An apparatus according to Claim 20 wherein the at least one reference point comprises a respective reference point on each of said pairs of adjacent outer edges.

26. An apparatus according to Claim 20 wherein the at least one reference point comprises a plurality of reference points for at least one of said pairs of adjacent outer edges.

27. An apparatus according to Claim 26 wherein said controller causes the laser beam to follow a predetermined function between successive points.

28. An apparatus according to Claim 27 wherein the predetermined function comprises at least

one of a linear function, a logarithmic function, a polynomial function, a power function, an exponential function, and a function based on a moving average.

29. An apparatus according to Claim 26 wherein said controller determines an average reference point based upon the plurality of reference points.

30. An apparatus according to Claim 20 wherein said laser provides an enlarged beam coverage area to weld each pair of adjacent outer edges despite slight errors in relative positioning of the laser beam and pair of adjacent outer edges.

31. An apparatus according to Claim 20 wherein said laser provides a plurality of laser beams to simultaneously weld multiple pairs of adjacent outer edges.

32. An apparatus according to Claim 20 wherein the bellows components comprise at least one end plate.

33. An apparatus according to Claim 20 wherein the bellows components comprise a plurality of bellows diaphragms.

34. An apparatus according to Claim 20 wherein said fixture comprises a rotatable arbor and a drive motor connected thereto.

35. A method of making bellows from bellows components, the method comprising:

supporting a plurality of bellows components
on a fixture in a side-by-side relation to define a
5 plurality of pairs of adjacent outer edges to be welded
together;

determining at least one reference point
relating to locations of the pairs of adjacent outer
edges of the bellows components; and

10 directing a laser beam so that the laser beam
welds together the pairs of adjacent outer edges based
upon the at least one reference point.

36. A method according to Claim 48 wherein
accepting comprises accepting a reference point on at
least one of said pairs of adjacent outer edges.

37. A method according to Claim 48 wherein
accepting comprises accepting a respective reference
point on each of said pairs of adjacent outer edges.

38. A method according to Claim 48 wherein
accepting comprises accepting comprises a plurality of
spaced apart reference points for at least one of said
pairs of adjacent outer edges.

39. A method according to Claim 38 wherein
directing comprises directing the laser beam to follow
a predetermined function between successive points.

40. A method according to Claim 39 wherein
directing comprises directing the laser beam to follow
at least one of a linear function, a logarithmic
function, a polynomial function, a power function, an
5 exponential function, and a function based on a moving
average.

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41. A method according to Claim 38 further comprising determining an average reference point based upon the plurality of reference points.

42. A method according to Claim 48 wherein accepting comprises accepting a reference point on said fixture

43. A method according to Claim 48 wherein directing is performed after determining the at least one reference point.

44. A method according to Claim 48 wherein directing comprises directing a laser beam having an enlarged beam coverage area to weld each pair of adjacent outer edges despite slight errors in relative positioning of the laser beam and pair of adjacent outer edges.

45. A method according to Claim 48 wherein directing comprises directing a plurality of laser beams to simultaneously weld multiple pairs of adjacent outer edges.

46. A method according to Claim 48 further comprising presenting an operator an image of at least one pair of adjacent edges and accepting from the operator an input to set the at least one reference point.

47. A method according to Claim 46 wherein presenting comprises presenting a magnified image of

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the at least one pair of adjacent edges.

48. A method of making bellows from bellows components, the method comprising:

supporting a plurality of bellows components on a fixture in side-by-side relation to define a
5 plurality of pairs of adjacent outer edges to be welded together;

presenting to an operator an image of the at least one pair of adjacent edges;

accepting from the operator an input to set
10 at least one reference point relating to locations of pairs of adjacent edges of bellows components supported on said fixture; and

directing a laser beam so that the laser beam welds together the at least one pair of adjacent outer
15 edges based on the at least one reference point.

49. A method according to Claim 48 wherein accepting comprises accepting an input to set a reference point on at least one of said pairs of adjacent outer edges.

50. A method according to Claim 48 wherein accepting comprises accepting an input to set a respective reference point on each of said pairs of adjacent outer edges.

51. A method according to Claim 48 wherein accepting comprises accepting an input to set a plurality of spaced apart reference points for at least

one of said pairs of adjacent edges.

52. A method according to Claim 51 wherein directing comprises directing the laser beam to follow a predetermined function between successive points.

53. A method according to Claim 52 wherein directing comprises directing the laser beam to follow at least one of a linear function, a logarithmic function, a polynomial function, a power function, an exponential function, and a function based on a moving average.

54. A method according to Claim 51 further comprising determining an average reference point based upon the plurality of reference points.

55. A method according to Claim 48 wherein accepting comprises accepting an input to set a reference point on said fixture.

56. A method according to Claim 48 wherein directing is performed after accepting an input to set at least one reference point.

57. A method according to Claim 48 wherein directing comprises directing a laser beam having an enlarged beam coverage area to weld each pair of adjacent outer edges despite slight errors in relative positioning of the laser beam and pair of adjacent outer edges.

58. A method according to Claim 48 wherein directing comprises directing a plurality of laser

beams to simultaneously weld multiple pairs of adjacent outer edges.

59. A method according to Claim 46 wherein presenting comprises presenting a magnified image of the at least one pair of adjacent edges.

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